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Status of sturgeon aquaculture and sturgeon trade in China: a review based on two recent nationwide surveys

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Summary

The authors reviewed the aquacultural history of Acipenseriformes in China, related the legal status and examined the current status of the cultured species or hybrids, origins of seedlings, quantities of production, geographic distribution in farming, and the sustainability for both restocking programmes and human consumption. The census shows that since 2000, the production of cultured sturgeons in China appears to have become the largest in the world. As of 2000, the rapid growth of sturgeon farming in China mainly for commercial purposes has shifted harvests in the Amur River from caviar production to the artificial culture of sturgeon seedlings. This dramatic development has also caused a series of extant and potential problems, including insufficient market availability and the impact of exotic sturgeons on indigenous sturgeon species. Annual preservation of sufficient higher-age sturgeons should be a national priority in order to establish a sustainable sturgeon-culture industry and to preserve a gene pool of critically endangered sturgeon species to prevent their extinction.

Introduction

There are eight indigenous species of Acipenseriformes in China: *Acipenser sinensis, A. dabryanus* and *Psephurus gladius* in the Yangtze River, *A. schrenckii* and *Huso dauricus* in the Amur River, *A. baerii* and *A. ruthenus* in the Irtysh River and *A. nudiventris* in the Ili River (Wei et al., 1997; Yang, 1997) (Fig. 1). Few studies have been conducted on *A. baerii*, *A. ruthenus* and *A. nudiventris* in China, but the wild populations are believed to be very small; subsequently, catches are rare. Although there is a lack of scientific information on the current status of sturgeons in the Chinese part of the Amur River, available catch figures indicate a significant decline in stocks of *H. dauricus* and *A. schrenckii* over the past decade because of overexploitation for caviar production (Wei et al., 1997; Sun et al., 2003; Wei and Yang, 2003). The over-harvest of sturgeons in the Amur River has stimulated the collection of broodstock for artificial reproduction, mainly for commercial aquaculture since 1999, in order to reduce fishing pressure on this species. Other threats to sturgeon species in China include habitat destruction and blockage of migration routes through hydro-dams. The construction of the Gezhouba Dam on the Yangtze River, for example, is a major threat to *A. dabryanus* and *P. gladius*, two species already believed to be on the verge of extinction (Wei and Yang, 1998). Their continued survival in the wild is further threatened by the disruption of their spawning grounds by the Jinshajiang First Hydroelectric Project. The Three Gorges project, the largest dam construction in China, will also further threaten the existence of the already endangered *A. sinensis* by significantly reducing water discharge of the river during the October–November spawning period (Chinese Academy of Science, Yangtze River Water Resources Protection Institute, 1996; Chang and Cao, 1999; Wei, 2003). Scientific investigations on various conservation aspects have been undertaken for *A. sinensis* (Wei et al., 1997; Chang and Cao, 1999). Studies using tag-recapture methods, population structure analysis and sonar counting indicated that the spawning stock of the species in the spawning area at Yichang had clearly decreased since the completion of the Gezhouba Dam (Chang, 1999; Wei, 2003). However, juvenile stocks of the species found at the mouth of the Yangtze River were stable or had even increased, likely due to satisfactory natural reproduction as indicated by the Coded Wire Tag (CWT) studies of the last 4 years (Wei, 2003; Yang et al., 2004). Harvest of *A. sinensis* in the Yangtze River is now restricted to the broodstock collection of 40 individuals annually for restoration purposes only. Conservation progress has been made for *A. sinensis* by reducing illegal fishing through public awareness campaigns, an initial restocking programme and through protection of spawning habitats. However, the Pearl River population of this species is believed to be close to extinction.

Current conservation measures for sturgeons and paddlefish in the Yangtze River include the strict limitation of harvest, the establishment of protected areas and the ongoing restocking programmes.

Sturgeon aquaculture can be used as a tool not only for economic development to meet the demand for products from these species, but also for restocking; thus culture can become a conservation tool (Burtsev et al., 2002; Chebanov et al., 2002). Furthermore, establishment of closed-cycle systems for maintaining captive broodstock may provide the quality control needed for the foundation of sustainable sturgeon farming while also serving as a tool for the preservation of the gene pool of endangered sturgeon species (Chebanov et al., 2002).

A large number of fertilized sturgeon eggs or prolarvae were also imported from Russia, France and Hungary (Sun et al., 2003; Wei and Yang, 2003). World sturgeon aquaculture production was only 1297 tonnes in 1996, and 2706 tonnes in 1999 (FAO Database, 2001; Raymakers and Hoover, 2002). Data provided by Bronzi et al. (1999) suggest these figures

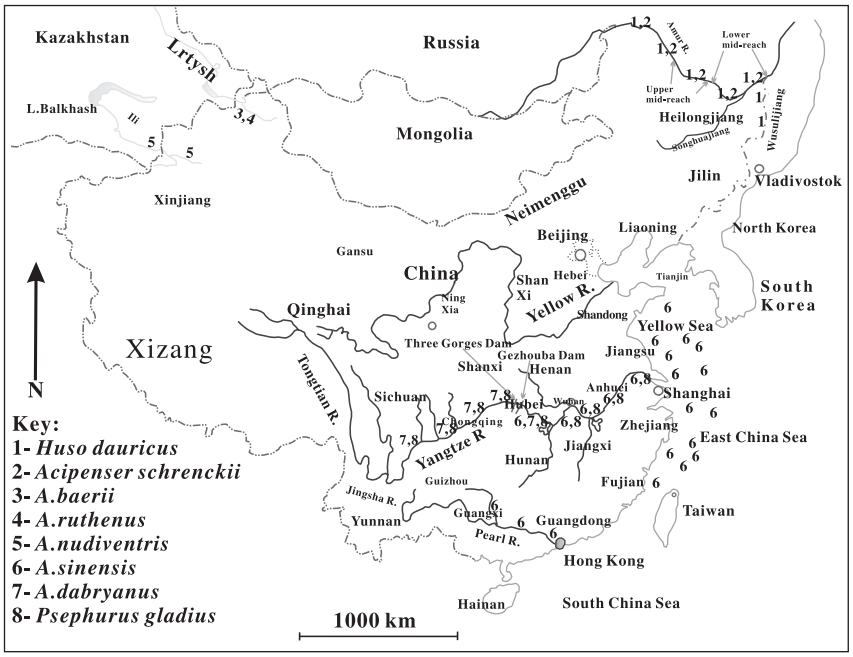

Fig. 1. Geographical distribution of indigenous species of Acipenseriformes in China

might be as much as 50% lower than the actual production. It is believed that China has become the largest sturgeon aquaculture country in the world as of 2000 (Wei, 2002; Wei and Yang, 2003). Negative impacts of large-scale farming on wild populations, such as the escape of exotic sturgeons, must be considered.

In 1998, 26% of the trade in live sturgeon specimens was destined for China, second only to the USA (28%). China dominates the market for imports of live specimens and fertilized eggs of the Mississippi paddlefish, *Polyodon spathula*, and imports 88% of all the USA sturgeon exports. While China was known to be a major – and perhaps the world's largest – producer of sturgeons from aquaculture operations, the extent and management of such operations and the status of trade in specimens from these operations were unknown. This study was therefore initiated to determine the status of captive breeding of sturgeon species in China and to tentatively assess the effects of aquaculture of indigenous and exotic species on the conservation measures of sturgeon populations in the wild. The study also examines regulations for trade in sturgeon specimens from China.

Materials and methods

This report is based chiefly on the findings of two independent surveys: (i) The Fisheries Bureau of Ministry of Agriculture of China (FB of MoA of China), in conjunction with the fisheries management authorities of provinces where sturgeons occur naturally or in culture, conducted a sturgeon aquaculture survey between spring and summer 2001 in order to improve management and regulation of aquaculture. (ii) The sturgeon research team of the Yangtze River Fisheries Research Institute (YFI) visited most of the large- and mid-size sturgeon farms in the region as well as the live-fish markets in the provinces of Guangdong, Fujian, Hubei, Jiangsu, Zhejiang and Heilongjiang and the municipalities of Shanghai and Beijing in order to undertake a special survey for TRAFFIC during March–July 2002. International trade is mainly based on permits approved by FB of MoA.

Legal status of sturgeons and paddlefishes in China

The Bureau of Fisheries of MoA is responsible for the protection of aquatic species (Office of Aquatic Wildlife Conservation of MoA, 2002). Total allowable catch is determined by the state government, with a quota allocated in accordance with Article 22 of the Fisheries Law of the People's Republic of China, enacted in 1986 and amended in 2000. Article 30 of this law prohibits the use of explosives, poisons, electricity and other destructive fishing methods, as well as prohibits fishing in restricted areas and during closed seasons. Prohibited fishing methods, restricted areas for fishing and closed seasons are determined by the Bureau of Fisheries under the MoA and by local governments at or above the county level.

In 1997, the MoA promulgated the 'Regulation on Management of Aquatic Wildlife and Plant Nature Conservation Area, People's Republic of China', which states that special nature conservation areas should be established for important economic and endangered wildlife species and their habitats. Sturgeons are regarded not only as important economic species but also as endangered species, the responsibility for their protection resting with the MoA.

Three native Acipenseriformes, *A. sinensis*, *A. dabryanus* and *P. gladius*, which chiefly inhabit the Yangtze River, were listed as Class I protected species under the Wild Animal Protection Law (WAPL) promulgated by the State Council in 1989. In accordance with Notification No. 48 (1993), issued by the Ministry of Forestry (now the State Forestry Administration), non-native species listed in Appendix I and II of CITES and imported into China are categorized as Class I and II protected species, respectively. Species of Acipenseriformes not previously listed in WAPL have been afforded protection as Class II-protected animals since 1997, when all species of sturgeons and paddlefish were listed in Appendix II of CITES.

Hunting, capture or killing of wildlife under Class I protection is prohibited, although scientific research, domestication, breeding or exhibition is allowed with a permit issued from the MoA (WAPL, Article 16). Hunting, capture or killing of wildlife under Class II protection is prohibited without a

permit issued by the Fisheries Authority of the Provincial Government (WAPL, Article 16). Sale, purchase or utilization of Class II state protected wildlife or their products is allowed only with a permit issued by the Fisheries Bureau of the Provincial Government (WAPL, Article 22).

Transportation within China of Class I- or II-listed species or their products must be approved by the Department of Wildlife Administration under the government of the relevant province, autonomous region or municipality (WAPL, Article 23). Violation of this provision would result in the confiscation by the Administrative Authorities for Industry and Commerce of the illegal products and any income derived from these products (WAPL, Article 35). If the circumstances are serious enough to constitute a crime, the person shall be prosecuted for criminal responsibility (WAPL, Article 35).

In 1999, the MoA also promulgated the 'Regulations on Special License of Aquatic Wildlife Utilization, People's Republic of China' whereby export and/or import of aquatic wild animals and their products that are restricted by international conventions must be approved by the FB of MoA after verification by the provincial fisheries authority. The harvest, propagation, culture, transport, exhibit, domestic and international trade of Class I protected species and their products require a permit issued by the MoA. The harvest, propagation, culture, transport, exhibit, domestic and international trade of Class II protected species and their products require a permit issued by the Provincial Fisheries Authorities.

Exports of species under state protection require permits issued by the CNMA after consultation with and agreement of the Endangered Species Scientific Committee (ESSC) – China's CITES Scientific Authority – and the FB of the MoA, in accordance with the 'Implementing Regulations for Aquatic Wildlife Protection' promulgated by the Ministry of Agriculture in 1993 and in accordance with WAPL, Articles 24 and 40. These permits are required to be cleared by Customs (WAPL, Article 24). More articles are involved in this respect in the 'Implementing Regulations on Aquatic Wildlife Protection of the People's Republic of China' (Articles 22 and 23) and 'Regulations concerning Special Licenses for Aquatic Wildlife Utilization' (Articles 3, 4 and 38–42).

Any persons who illegally import or export specimens of species under state protection or CITES-listed species will be punished according to the Customs Law and, if the circumstances are serious enough to constitute a crime, they shall be prosecuted for a criminal offense under the Criminal Law (WAPL, Article 36). If the provisions of CITES differ from those stated in WAPL, the provisions of CITES apply unless China has a specific reservation on the species in question (WAPL, Article 40).

In 1994, The People's Republic of China and Russia signed the 'Protocol on Fisheries Resources Conservation, Regulation and Multiplication in the Border Areas of Heilongjiang (Amur) River and Wusulijiang River of The People's Republic of China and the Russian Federation'. *Acipenser schrenckii* and *H. dauricus* are major subjects for conservation, enhancement and management in this protocol.

Implementation of legal instruments regarding sturgeon

At present, permits for the export and import of sturgeons, their parts and derivatives, are issued by the China CITES Management Authority after approval by the FB of the MoA. However, the China CITES Scientific Authority is rarely consulted.

In January 2002, the MoA approved and set up the 'Aquatic Wild Fauna and Flora Administrative Office of the Ministry of Agriculture' (AWO of MoA) that is specifically responsible for management of aquatic endangered species in China, including the administration of import/export, except for issuance of export/import permits. 'The Scientific Commission of Aquatic Endangered Species' of the MoA has been established to provide a scientific foundation on aquatic endangered species for stock assessment, the making of laws or regulations, conservation and import/export decisions.

At present, caviar export quotas of *A. schrenckii* and *H. dauricus* are set by the FB of MoA in coordination with the China CITES Management Authority. These quotas are based on production figures of the previous year, as reported by the Heilongjiang Fisheries Bureau. Harvest quotas of sturgeons (for caviar production and for specimens destined for propagation) are based upon the sturgeon quota established for caviar production.

Only licensed traders can obtain permits for sturgeon import or export in Heilongjiang Province, and they must submit an application to the local fisheries authority. The application is then sent to the Provincial Fisheries Authority, thereafter to the FB of MoA, and finally to the China CITES Management Authority; the permit application must be approved at each step. However, because there are very few fisheries experts in the China CITES Scientific Authority, the FB of the MoA or the AWO of MoA have to consult fisheries experts nationwide to make decisions on CITES issues. The FB of the MoA and the China CITES Scientific Authority do not always agree upon applications or quotas, including the caviar export quotas.

Status of sturgeon aquaculture in China

By means of collection of mature broodfish in relevant spawning grounds and of injection of pituitary hormones, artificial reproduction was initially successful in China for *A. schrenckii* in 1957 (Zhang, 1985), for *A. sinensis* in 1972 and for *A. dabryanus* in 1976 (Anonymous, 1988). These early studies could not resolve techniques for mass rearing of juveniles on a commercial scale. Sturgeon aquaculture techniques were gradually developed during the 1990s, mainly for restocking programmes in the Yangtze and Amur rivers (Chen and Zhou, 1992; Wei et al., 1997; Chang and Cao, 1999; Zhuang et al., 2002; Sun et al., 2003). During April 1990, the American paddlefish were first introduced into China from the USA for commercial purposes (Wu and Lin, 1999). Paddlefish eggs were transferred intercontinentally and incubated in Hubei Province. Juveniles were raised in earthen ponds or stocked into water reservoirs (Wu and Lin, 1999). The Dalian Russian Sturgeons Cultivating Corporation (a China–Russia Joint Venture) was set up at Wafangdian Dalian in 1993. Since this time, the company has imported a large number of fertilized eggs of sturgeon hybrids, sterlet and Russian sturgeon as well as American paddlefish for commercial farming (Leng and Cao, 1999). A hatchery in Beijing also began to import fry and fertilized eggs of Siberian sturgeon from France in 1996. Fingerlings were produced and sold to hatcheries in parts of southern China (e.g. Guangdong Province). To conduct a study on sturgeon aquaculture, fry of *A. schrenckii* (Amur River stock) were reared in a hatchery in Heilongjiang and moved south to a hatchery in Ji'nan, Shandong in 1995 as well as one in Jingzhou, Hubei in 1997 (Zhuang et al., 2002; Sun et al., 2003; Wei and Yang, 2003).

A series of experiments showed that aquaculture of sturgeons could be successful in the warm waters of southern China and could have great economic potential (Zhuang et al., 2002). Sturgeon farming in China has increased in popularity since 1998 (Sun et al., 2003; Wei and Yang, 2003). As a result, sturgeons have been harvested in the Amur River not only for caviar but also to obtain broodstock for commercial aquaculture.

Origins of species produced in aquaculture

With the exception of *A. schrenckii* for which a second generation offspring was successfully raised in a closed-cycle hatchery in May 2002 (Qu et al., 2002), all sturgeons cultured in China are either reared from imported eggs/juveniles or reared from eggs or fry obtained in the wild. As of 2002, there are 11 sturgeon species/hybrids being cultured in China (see Table 1).

Amur River. Up to the present, the major cultured species in China, *A. schrenckii*, *H. dauricus* and hybrids of *A. schrenckii* × *H. dauricus* (or reverse crosses), have been obtained from artificial propagation using wild spawners caught in the Amur River. Adult sturgeons caught by licensed fishermen are collected by hatcheries that are also caviar producers. Some of the fish are selected for breeding; the remainders are processed for caviar.

Every spring and summer since 1998, fertilized eggs, embryos or fry from Heilongjiang (from the seven hatcheries noted later in the report) have been delivered to the southern and central areas of China by air. Fingerlings were reared primarily in Guangdong, Fujian, Hubei, Shanghai, Jiangsu, Beijing and Shandong and then sold or distributed to the other sturgeon farms.

Yangtze River. All cultured *A. sinensis* originated from artificially fertilized eggs of wild broodstock carried out by the Chinese Sturgeon Institute at Yichang and the YFI at Jingzhou, both located in Hubei Province (Wei and Yang, 1998; Chang and Cao, 1999). The two institutes receive special licenses on a yearly basis to capture a few to multiple spawners for restocking programmes and research projects. With improvements in techniques and facilities, after 1998 over 50% of post-spawners survived and were returned to the river. In recent years, the central government (FB of the MoA) granted permits to several hatcheries and companies to raise Chinese sturgeons to try to complete closed-cycle captive breeding in case the species becomes extinct in the wild because of the additional impact of the Three Gorges Project. *Acipenser sinensis* was found to be the best candidate for aquaculture because of positive characteristics such as rapid growth, low susceptibility to diseases, low feed conversion coefficient and high quality meat. Aquaculture of this species may greatly help species conservation by supplying the market, the provision being that *in situ* protection measures are synchronously taken and strictly enforced.

Import. Eggs and embryos of seven sturgeon species were imported into China from 1999 to 2001 (Table 2). Although CITES import permits indicate that 4.05 million, 8.8 million and 6.59 million sturgeon eggs/embryos were imported in 1999, 2000 and 2001, respectively, actual imports were lower than the approved numbers because exporting countries could not meet the demand, particularly in 2001. Actual imports for 2001 are unknown, although available figures provide some indication of levels of trade and demand. The countries of origin were mainly Russia (for Russian sturgeon, sterlet, Russian hybrids, sevruga, beluga and Mississippi paddlefish), France and Hungary (for Siberian sturgeon). Four importers located in Beijing accounted for about 90% of the total imports. In recent years aquaculture of Russian sturgeon (*A. gueldenstaedtii*) has declined because the yellow colour and coarse meat of this species is not very highly valued by the Chinese. Recent imports are mainly comprised of Russian hybrids and the Siberian sturgeon.

Fry production

Geographical distribution and producing capacity. All cultured Amur and Kaluga sturgeons and their hybrids were spawned in Heilongjiang from eggs obtained from wild specimens. The Chinese sturgeon, the eggs of which were also obtained from wild populations, were hatched in Hubei, whereas the majority of sturgeon specimens imported into China were hatched in Beijing.

Fingerling production of almost all sturgeon species, however, has mainly shifted to the provinces of Guangdong, Fujian, Hubei and Jiangsu and the municipalities of Shanghai

Table 1
Sturgeon species/hybrids raised in captivity in China, results of surveys undertaken in 2001–2002

English name	Scientific name	Major range states	Minimum age of sexual maturity of female in nature
Amur sturgeon	*Acipenser schrenckii*	China, Russia	9
Amur hybrids	*A. schrenckii* × *Huso dauricus* or reversed cross	China, Russia	
Kaluga	*Huso dauricus*	China, Russia	18
Russian sturgeon	*A. gueldenstaedtii*	Russia, countries around Caspian Sea	12
Russian hybrids	*H. huso* × *A. ruthenus* or other cross	Russia, countries around Caspian Sea	
Siberian sturgeon	*Acipenser baerii*	Russia, Kazakhstan, China	11
Sterlet	*A. ruthenus*	Russia, Romania, Eurasian countries	4
Stellate or sevruga	*A. stellatus*	Russia, countries around Caspian Sea	7
Chinese sturgeon	*A. sinensis*	China	13
Mississippi paddlefish	*Polyodon spathula*	USA	8
Beluga	*Huso huso*	Russia, countries around Caspian Sea	16

Table 2
Reported imports (ind. × 10 000) into China of fertilized sturgeon eggs or embryos, 1999–2001

Species	1999	2000	2001
Acipenser gueldenstaedtii	275	285	100
Russian hybrids	90	165	186
A. ruthenus	25	75	20
A. baerii	10	340	330
A. stellatus	25	20	
Huso huso	25		
Polyodon spathula			59.8
Total	405	880	659.8

Source: Fisheries Bureau, Ministry of Agriculture, 2002.

and Beijing. Sturgeon fingerling production capacity is provided in Table 3.

According to the visits of the survey team as well as correspondence with hatchery locations that were not visited, it was estimated that sturgeon aquaculture operations in China occur in about 70% of the surveyed areas, which includes about 20 of the provinces/municipalities of China. These are Anhui, Chongqing, Guangxi, Guizhou, Hainan, Heilongjiang, Henan, Hunan, Jiangxi, Liaoning, Shangdong, Shanxi, Sichuan, Yunnan, in addition to the eight surveyed (see Material and Methods). Fry and fingerling production capacity from the surveyed farms is estimated to comprise only about 50% or less of all Chinese sturgeon fry and fingerling production farms. It is therefore estimated that total production in China of sturgeon fingerlings (up to 10 cm size) could be as high as 20 million fingerlings.

Standing stock in culturing

Fry. *Chinese sturgeon* As of 1999, fry production of this species in China has been well-documented. Each year for the past 3 years, two institutes (CSI and YFI) received special licenses from the FB of the MoA to capture Chinese sturgeon spawners for artificial propagation with a quota of 20 spawners in 1999, 26 spawners in 2000 and 14 spawners in 2001. Fry production was about 1 000 000, 2 000 000 and 800 000 in 1999, 2000 and 2001, respectively. About 30–50% of the fry were reared for restocking; the remainders were sent to farms that had been licensed for grow-out of the species. Since 1998, a total of 11 farms and companies in China have been granted permits for aquaculture of the Chinese sturgeon.

Table 3
Sturgeon production capacity in the surveyed hatcheries or farms (2002)

		Fry production	
Province/ municipality	Number of farms surveyed	Tank area (m^2)	Capacity for rearing to 10 cm (×10 000)
Guangdong	8	31 526	315
Fujian	5	8560	85
Hubei	13	25 866	259
Jiangsu	5	9818	98
Shanghai	4	12 000	120
Zhejiang	2	3690	37
Beijing	2	6500	65
Total	39	90 715	907

Four of these farms are located in Guangdong Province, two in Fujian Province, four in Hubei Province and one in Jiangsu Province. However, commercial utilization of these reared fish has not been permitted.

Amur and Kaluga sturgeon and their hybrids The second survey revealed that 25.8 million and 43.3 million fertilized eggs and fry of Amur sturgeon or Kaluga/Amur hybrids were produced in Heilongjiang in 2001 and 2002, respectively (Tables 4 and 5). According to the outcome of the survey, the authors estimate that the farms managed to achieve about 50% survival from egg to fry. The final number of fry (or prolarvae) was perhaps about 13 million and 26 million in 2001 and 2002, respectively. Both *A. schrenckii* and *H. dauricus* only reproduce in May–June (Wei et al., 1997). Thus, the surveyed volumes of fertilized eggs and hatched prolarvae produced during April–June represent incubation efforts of the entire year although a few activities in artificial spawning occurred in autumn, but with little success.

Most fertilized eggs were quickly transported to provinces in the south of China for incubation. Some fry in the southern hatcheries or farms were maintained for grow-out and some were sold to other fish farms. Despite the requirements for licenses to transport, culture and sell sturgeons, it was extremely difficult to obtain detailed and reliable information on the transportation routes and the quantities distributed.

Imported sturgeons The information available on imports of eggs is depicted in Table 2. When hatching rates were around 50%, more than 2 million fry should then have been produced each year between 1999 and 2001. Most of the hatchlings were also distributed to the eight major sturgeon aquaculture provinces/municipalities.

Fingerlings Surveyed were a total of 39 farms or hatcheries in the eight provinces that were the major producers of sturgeon fry in China.

Table 6 shows the quantities of sturgeon fingerlings produced in the 39 farms surveyed; the overall standing stock achieved was 8.93 million fish. It is estimated that the total number should be doubled to represent the total production in the country. Between 1998 and 2000, the largest sturgeon farming areas were located in Guangdong, particularly in the Pearl River delta. In 2000, the sturgeon culture centre moved to the Yangtze delta, mainly to Jiangsu and Shanghai. Another trend in farming sturgeons is that the Amur sturgeon is now the most common of farmed species in the country, accounting for 70.8% of the total number of cultured specimens (Table 6).

Based on the current sturgeon-rearing techniques in China, survival rate from fingerling to grow-out size (above 0.75 kg) can usually be expected to be about 50%. Growing fry to an average of 0.75 kg size takes about 12 months on average (for all sturgeon species). The authors thus predict from the farms surveyed that approximately 3350 tonnes of sturgeons with an average size of 0.75 kg should be ready for the market after 1 year (i.e. in mid-2003), and that total production across China would be over 6000 tonnes.

Grow-out production

Since there have not been any national or governmental programmes with a certain guaranteed investment to preserve sturgeons via aquaculture as a tool, very limited sturgeon

Table 4
Quantity (×10 000) of fertilized eggs (embryo) and fry of sturgeons produced in hatcheries in Heilongjiang Province from April 2001 to June 2001, census undertaken by the sturgeon survey team in 2001 and 2002

Number of Hatchery	Amur sturgeon		Kaluga		$AS_f \times K_m$		$AS_m \times K_f$	
	Embryo	Fry	Embryo	Fry	Embryo	Fry	Embryo	Fry
1	400	30	0	0	50	0	0	0
2	300	0	0	10	40	0	0	0
3	100	0	0	0	30	0	0	0
4	300	0	0	0	0	0	40	0
5	300	0	0	0	80	0	0	0
6	350	0	0	0	100	0	0	0
7	330	0	0	0	0	0	0	0
Others	100	0	0	0	20	0	0	0
Total	2180	30	0	10	320	0	40	0

AS_f (or AS_m) = females (or males) of *Acipenser schrenckii*; K_f (or K_m) = females (or males) of *Huso dauricus*.

Table 5
Quantity (×10 000) of fertilized egg (embryo) and fry of sturgeons produced in hatcheries in Heilongjiang Province from April 2002 to June 2002, census undertaken by the sturgeon survey team in 2001 and 2002

Number of Hatchery	Amur sturgeon		Kaluga		$AS_f \times K_m$		$AS_m \times K_f$	
	Embryo	Fry	Embryo	Fry	Embryo	Fry	Embryo	Fry
1	1200	80	0	0	160	0	0	0
2	280	0	0	0	28	0	0	0
3	150	300	0	15	70	35	0	30
4	300	30	0	0	0	0	0	0
5	30	70	0	0	0	0	0	0
6	350	150	0	0	0	0	0	0
7	330	200	0	0	20	0	0	0
Others	400	0	0	0	100	0	0	0
Total	3040	830	0	15	378	35	0	30

AS_f (or AS_m) = females (or males) of *Acipenser schrenckii*; K_f (or K_m) = females (or males) of *Huso dauricus*.

Table 6
Standing fingerling stock in raising by each surveyed province (July, 2002)

Province	Number of farms surveyed	Fingerlings (×10 000) by species					
		AS	AH	RH	CS	Others	Total
Guangdong	8	138	38	3.8	0	0	179.8
Fujian	5	87	17	0	0	7	111.0
Hubei	13	57.5	16	0	0	0	73.5
Jiangsu	5	211	19.5	4.5	0	44	279
Shanghai	4	50	25	0	0	29	104
Zhejiang	2	8.5	0	2.2	0	0	10.7
Beijing	2	80	5	20	0	30	135
Total	39	632	120.5	30.5	0	110	893

AS = *Acipenser schrenckii*; AH = Amur hybrids; RH = Russian hybrids; CS = *A. sinensis*; Others = imported and indigenous species found in China excluding the four aforementioned.

culture facilities are employed for conservation purposes in China. As the Chinese sturgeon is listed nationally as a Class I state protected animal, the people who are permitted to culture them have also the obligation to restock these to natural waters or 'preserve' them in captivity, while legally not being allowed to sell them. Illegal trade does, however, occur from time to time. Commercial investment has made a contribution to conservation of the Chinese sturgeon in the form of large-scale restocking programmes and preservation of captive stocks as a 'conservation back-up system'. The recruitment of juveniles in the mouth of the Yangtze River has fortunately increased recently, while the number of wild spawners actively caught for restocking purposes has decreased because facilities and rearing techniques have been much improved.

However, commercial use of the Chinese sturgeon is strictly prohibited. There have been many discussions on the potential exploitation and commercial use of Chinese sturgeon because of successful rearing in aquaculture facilities. Persons taking part in these discussions included representatives of the Chinese People's Political Consultative Conference and the deputies of the National People's Congress.

Production capacity. Additional to increasing the number of new tanks built solely for sturgeon culture, more than half of the culturing facilities were modified from eel culture ponds, mainly located in Fujian Province. Furthermore, soft-shell turtle ponds (in Hubei Province) have also been converted into sturgeon-rearing ponds and even common earthen ponds, such as in Guangdong, now serve as sturgeon culture facilities. In recent years, net cages have also proved to be very successful for rearing sturgeon in Guangdong (mainly in rivers) and Hubei (mainly in water reservoirs). Raising sturgeon in net cages has many advantages such as lower operational costs, less disease and better product quality. Net cages also provide a huge capacity for sturgeon culture. However, net cage culture poses some risks, such as unforeseen potential for

escapement and disease outbreaks in long-term growing cage cultures as well as pollution from own and other activities. Exotic sturgeon escapes may cause severe ecological problems, including threatening native sturgeons once these exotics become established or hybridize with native sturgeons. Furthermore, niche replacement by invasions is a substantive threat. Net cage culture operations should be restricted to closed waters. If exotic species of Acipenseriformes are reared in relatively open waters such as reservoirs connected with sturgeon rivers, then measures of highly secure blocking of fish migrations should be taken to prevent fish from escaping into sturgeon rivers, including the Yangtze and the Amur. Recently the Chinese government has planned to fund some studies on the effects of exotic species invasions on ecosystems, including those of imported sturgeons. The status of disease, disease transfer and water contamination caused by sturgeon culture in net cages is unknown and requires investigation.

Table 7 shows that the maximum sturgeon production capacity for the 39 sturgeon farms surveyed is 7860 tonnes. Current production is estimated to be around 3350 tonnes (42.6% of total production capacity). Total production capacity for the entire country would therefore be approximately 15 700 tonnes.

Standing stock. Table 8 shows that the standing biomass in culturing totaled 760.6 tonnes of fish from 1 to 8 years of age. Most of the 1-year-old sturgeon in the 39 farms had been sold.

Status of sturgeon in captivity

Sturgeon restoration should consist of harvest control, habitat protection or restoration (especially spawning ground protection) and conservation of sturgeon biodiversity, as well as restocking when needed. Since the conflict between the human population and nature (environment and resources) is very prominent, conservation of wild fish appears to be quite significant. On the contrary, successful breeding of sturgeon in captivity is the key to establishing a sustainable sturgeon culture industry, which will help with sturgeon conservation.

Unfortunately, most sturgeon farms could not establish sustained captive breeding programmes because of economic restrictions. There are very few pre-spawning fish 6 years or older in hatcheries. Thus far, no sturgeon species complete their life cycle in a hatchery except for Amur sturgeon. Because of the dramatically declining trade price, almost all cultured sturgeon except for the Chinese sturgeon were sold before they weighed 1 kg. Without grants, commercial fish farmers could not afford to raise sturgeon to maturity.

In May 2002, captive breeding of Amur sturgeon was successful in Beijing (Qu et al., 2002). Two females, the offspring of wild parents through artificial breeding in the spring of 1995, were induced by hormone injection. One female spawned eggs which hatched out about 8000 fry, the first successful captive breeding of Amur sturgeon in the world.

We took a census of the captive population of the Chinese sturgeon and Amur sturgeon older than 3 years (see Table 9).

Table 7
Sturgeon producing capacity in the surveyed hatcheries or farms (2002)

Province/ municipality	Number of farms	Tank/raceway (m^2)	Capacity (tonnes)	Net cage (m^2)	Capacity (tonnes)
Guangdong	8	15 000	300	84 800	2544
Fujian	5	49 347	987	0	0
Hubei	13	55 000	1100	45 000	1350
Jiangsu	5	32 100	642	0	0
Shanghai	4	38 240	765	0	0
Zhejiang	2	6600	132	0	0
Beijing	2	2000	40	0	0
Total	39	198 287	3966	129 800	3894

Trade of sturgeon products for human consumption

Sturgeons were considered to be a new aquaculture object just like shrimp, Japanese eel and soft-shell turtles which all experienced large market surges. The sturgeon culture industry might follow in this path if the current situation continues. The present form of the sturgeon farming industry is only 3 years old. The cultured sturgeon has been used as food, with almost all sold as live fish; some companies have tried to develop medicinal uses for sturgeon but have no products as yet available for sale. A company in Shanghai that we visited had invested more than a million CN Yuan (about $120 000) in 2001 to try to develop a processed or convenience food from sturgeon, but it was not accepted at the market. As an acceptable market for cultured sturgeon could not be found, the market price declined sharply. Production increased by 50 times whereas the market price dropped by 10 times (Fig. 2).

Domestic trade

Most of the cultured sturgeons were sold on the domestic market (Table 10). As sturgeons are not a traditional food of the average Chinese and not easy to cook, fish have to be sold to restaurants. The Chinese preference to eat whole and live fish makes fish over 1 kg in size unacceptable. However, growing such small sturgeon increases culturing costs. The average cost, for instance, of Amur sturgeon production

Table 8
Standing stock of grow-out sturgeon in aquaculture facilities by each surveyed province (July, 2002)

Province/ municipality	Number of surveyed farms	Standing biomass (tonnes) by species					
		AS	AH	RH	CS	Others	Total
Guangdong	8	23	12	2	15	2	49
Fujian	5	92.5	94	2	65.5	1.5	255.5
Hubei	13	66	2	4	234	17	323
Jiangsu	5	9.6	1	1	6.3	0.2	18.1
Shanghai	4	76	0	0	0	12	88
Zhejiang	2	20	0	0	0	0	20
Beijing	2	3	1	1	0	2	7
Total	39	290.1	110	10	320.8	34.7	760.6

AS = *Acipenser schrenckii*; AH = Amur hybrids; RH = Russian hybrids; SC = *A. sinensis*; Others = imported and indigenous species found in China excluding the four aforementioned.

Table 9
Captive population (age 3–8) of *Acipenser sinensis* and *A. schrenckii* in China in 2002

Age (year)	*Acipenser sinensis* (ind.)	Location/Number (ind.)	*Acipenser schrenckii* (ind.)	Location/ number (ind.)
3	2000	Jingzhou Jiangsu/15	>2000	Jingzhou, Jiangsu, Shanghai, Fujian, et al.
4	600	Jingzhou/150 Guangdong/100 Fujian/300	4000	Shanghai/4000
5	1200	Jingzhou/500 Guangdong/200 Fujian/500	500	Jiangsu/200
6	10	Yichang, Hubei Province	230	Jingzhou/150 Yichang/80
7			690	Shandong/390 Jiangsu/200 Sichuan/100
8	5	Yichang, Hubei Province	20	Shandong/10 Beijing/10

was about 30 CNY kg^{-1} ($3.6 USD kg^{-1}) last year, which consisted of 8 CNY in fry, 16 CNY in feed and 6 CNY in operation and labour. This means the cost of fry accounted for 27% of the total. With this system, no fish are grown to maturity in hatcheries to be used as broodstock; thus both culturists and customers lose out and sturgeon resources are wasted.

Our survey (July 2002, Table 10) shows that at present, the wholesale price of live sturgeon of 0.8 kg size in Guangdong ranged from USD 1.7 kg^{-1} (CNY 14 kg^{-1}) to USD 2.9 kg^{-1} (CNY 24 kg^{-1}), with an average of USD2.5 kg^{-1} (CNY 21 kg^{-1}). However, generally the price in the northern part of China was higher than in the southern part. The average trade price in Xinjiang could reach CNY 100 kg^{-1} while it was only CNY 50 kg^{-1} in Shanghai and CNY 56 kg^{-1} in Beijing. Live sturgeons were found for sale in most of the provincial capitals and large cities of China. They were mainly shipped by air and could be transported live by truck, bus or even by train.

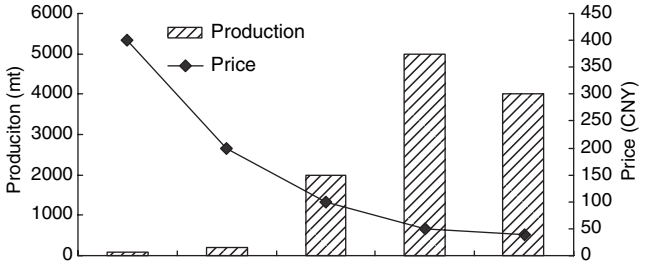

Fig. 2. Trends in production and trade prices of cultured sturgeons in China from 1998 to 2002

International trade

Caviar. The only legal sturgeon caviar trade in China was the export of caviar from wild populations of *A. schrenckii* and *H. dauricus* caught by Chinese fishermen in the Amur River. According to the MoA, the volume of caviar in 2000 was 5375 kg (2920 kg of Amur sturgeon, 2455 kg of Kaluga) and was permitted for export to Germany, USA and Japan. In 2001, the permitted and exported volume was 3000 kg (Table 11). The quotas established for 2000 by CITES were 2510 kg for Amur sturgeon and 3140 kg for Kaluga. The actual exported values were within the range of CITES quotas.

Sturgeon products other than caviar. International trade was limited mainly to whole fish and a small number of live fish.

Table 11
Sturgeon caviar export from China in 2000 and 2001 (from Fisheries Bureau of MoA)

Destination Country	Species caviar from	Quantity (kg) 2000	2001
Germany	*Acipenser schrenckii*	970	204.9
	Huso dauricus	1230	345.1
USA	*A. schrenckii*	230	0
	Huso dauricus	270	0
Japan	*A. schrenckii*	1255	960
	Huso dauricus	1420	1490
Total		5375	3000

moA, Ministry of Agriculture.

Table 10
A trade survey in fish markets in Shanghai and Guangzhou (July, 2002)

Year	*A. schrenckii* Daily sales (kg day^{-1})	Fish size (kg)	Unit price[a] (CNY kg^{-1})	Other sturgeon daily sales (kg day^{-1})	Fish size (kg)	Unit price[a] (CNY kg^{-1})
Huang Sha Trade Market Guangzhou (number of wholesale, 10)						
2001	2000	0.8	46–60	500	1.5	40–45
2002	1000	0.8	24–32	200	1.5	20–22
Tong Chuan Lu Aquatic Product Market, Shanghai (number of wholesale, 3)						
1999	20–50	1–3	360	20–50	1–3	360
2002	180	<0.75	50			

[a]wholesale price.
CNY = Chinese Yuan.

All of the exported fish prepared as meat for human consumption were from aquaculture.

Seven and a half tonnes of Siberian sturgeon (*A. baerii*), Russian sturgeon (*A. gueldenstaedtii*) and Amur sturgeon (*A. schrenckii*) were exported to Singapore (2.5 tonnes) and Hong Kong in 2000. The exported volume increased to 123 tonnes in 2001, which included Amur hybrids, Siberian sturgeon, Russian sturgeon, Amur sturgeon and sterlet. Destinations were Hong Kong and Japan (950 kg).

Sturgeon restocking programme

Yangtze River

History of the programme, restocking status and sustainability. Because Yangtze sturgeon, *A. dabyranus* and Chinese swordfish, *P. gladius* are too rare for capture of sufficient broodfish for artificial propagation, the restocking programme for sturgeons has so far only involved Chinese sturgeon (*A. sinensis*). The Chinese sturgeon restocking programme was initiated because the Gezhouba Dam blocked its migratory passage to the original spawning grounds. However, there is no specific fund for the sturgeon restocking programme as yet and there are no relevant restocking plans or guidelines for stocking numbers, sizes, locations or times.

To date, two institutes have been involved in the restocking programme for sturgeons. (i) The YFI of the Chinese Academy of Fishery Science, a national institution mainly engaged in freshwater fisheries research, has been responsible for assessment of sturgeon stock and restocking effectiveness. The YFI has carried out scientific research projects related to the Gezhouba Dam since its construction in 1981. Since funding for restocking was very limited and mainly originated from separate research projects, the YFI could not continue sustained restocking. (ii) The Chinese Sturgeon Research Institute (CSI) of the Gezhouba Group Inc., a business institute, took over restocking efforts for the Chinese sturgeon. Their restocking programme aimed to enhance sturgeon stock and involved a yearly release of a certain number of sturgeon fingerlings into the Yangtze River, intended to serve as a compensation for impacts of the dam. However, these efforts were constrained by the plan to release only 10 000 fingerlings per year. Over the past 10 years, the CSI faced heavy financial shortages because of the general increase in costs in China as well as the system problems of the institute. Before 1996, because of both technical and financial problems, releases were restricted mostly to sturgeon fry, an age too young to expect reasonable returns (see Table 12).

Since 1999, only fingerlings over 10 cm were restocked as a result of both technological improvements and increased funding by commercial investors that allowed for longer on-growing. The investors believed that commercial usage of cultured sturgeons could be permitted by the government through amending relevant regulations. There have been some precedents in this case, such as with regulations for the Chinese alligator, *Alligator sinensis* and spotted deer (*Cervus nippon*), which remain Class I protected animals under the 'Wild Animal Protection Law'. As a result, more fingerlings (more than 100 000) were stocked each year since 1999 than the total number stocked in the previous 16 years between 1983 and 1998 (see Table 12). Releases are usually in the middle reach of the Yangtze River near the spawning grounds Yichang or Jingzhou. Besides the two institutes, 3080 juveniles (total length: 38–58 cm) of the Chinese sturgeon were released into the Yangtze estuary by the East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, on 27 June 2001. The stocking was supported by a water channel construction company in Shanghai.

The number and quality of stocked fish have to be supervised by the local fisheries management authority. Since 1999, it has been become obligatory that sturgeon releases must be notarized by a local notary public.

As the Chinese sturgeon spawns in autumn (October–November), hatching and rearing have to be indoors using heated systems to advance growth; thus maintenance expenses are very high. The restocking programme will not be sustainable if specific funding is not set up or if the already limited commercial aquaculture and use of sturgeon products are fully prohibited.

Restocking capability. Stock assessments of the Chinese sturgeon populations have been tried by various methods including sonar counting, tag-recapture, population structure analysis and natural spawning monitoring. These attempts indicated that the number of adults annually entering the spawning reach (about 30 km length) at Yichang was between 500 and 1500 individuals, with a sex ratio ranging from 1 : 1 to 1 : 5 (female : male) during 1997–2003 (Chang, 1999; Wei, 2003). The number of juveniles occurring in the estuary of the Yangtze River appeared to be stable or experienced a slight increase (Chang, 1999; Wei, 2003). It is currently assumed that aquaculture taking 10% of the spawners is acceptable and that it should not significantly affect the recruitment capacity of the population. If 50 females are harvested for breeding, more than 2.5 million fingerlings could be produced annually.

Well-developed hatching and rearing facilities are now available, totaling more than 20 000 m^2 of tank water surfaces.

Table 12
Restocked number of Chinese sturgeon during 1983–2001

		By CSI		By YFI		
	Fish size (TL, cm)	Yangtze River	Pearl River	Yangtze River	Ming River (Fujian)	Pearl River
1983–1998	50–87	443	10	100	400	100
	10–15	62 500	2000	26 500	0	15 000
	2.5–3.5	4 260 000	0	1 496 000	0	0
	Total	4 322 943	2010	1 522 600	400	15 100
1999–2001	50–90	0	150	300	0	150
	10–15	150 000	2000	150 000	0	60 000
	Total	150 000	2150	150 300	0	60 150

CSI, Chinese Sturgeon Research Institute at Yichang Hubei; YFI, Yangtze River Fisheries Research Institute at Jingzhou Hubei (Wei, 1998 and unpublished data); TL, total length.

These are located at scientific institute farms or at commercial farms in Hubei Province. These facilities have the capacity to hold and rear more than 3 million Chinese sturgeon fingerlings and are available for use by the CSI and the YFI.

Amur River

History, restocking status and sustainability. The first sturgeon propagation station on the Chinese side of the Amur River was set up at Qingdeli in 1988. About 900 000 fry and 168 000 juveniles were released into the Amur River between 1988 and 1991. According to official reports of the Heilongjiang Fisheries Bureau, a total of 3.8 million fry and juveniles were stocked by the station into the Amur River. In the past 3 years the station had not undertaken any stocking because of lack of funding, but was stimulated by commercial interests in the selling of eggs.

A sturgeon propagation station was established in Fuyuan County in 1999, which used to be a salmon propagation station. The station is so far the biggest sturgeon hatchery on the Amur River and is the nearest station to the sturgeon fishing grounds, providing an opportunity for easier access to the broodstock and reducing transport stress of mature adults to the facility.

Because sturgeon fry have become a very profitable commodity, artificial propagation remains largely uncontrolled since 1999. Live sturgeon or sturgeon eggs are now used for breeding or rearing rather than for caviar production. In this survey study, it was difficult to estimate how many people or farms were currently engaged in artificial propagation. It must be assumed that fish are also illegally caught or poached and stimulated to spawn by injection of hormones in order to collect the fertilized eggs.

The government tried to control this situation by issuing special licenses. To date, seven hatcheries in Heilongjiang have been granted rights to engage in sturgeon propagation (see Table 13). Most of these hatcheries raise sturgeons primarily for commercial purposes; two (No. 1 and No. 3 in Table 13) hatcheries are also involved in some restocking. However, all hatcheries granted licenses are required by the Heilongjiang Fisheries Bureau to stock fingerlings into the Amur River. A resource fee of \$5.8 USD per 1000 fertilized eggs must be paid if fertilized eggs or embryos are sold (Source: Heilongjiang Fisheries Bureau, July 2002).

Also, fishermen increased the price of sturgeon to almost as high as the price for unprocessed roe. A healthy female *A. schrenckii* suitable for breeding cost approximately \$157 kg^{-1} in 2001 and \$240 kg^{-1} in 2002. Kaluga females cost about 70% of the price for *A. schrenckii*, mainly because the possibility of successfully breeding Kaluga is much lower than for *A. schrenckii*. High prices for mature sturgeon made many hatcheries unprofitable when solely serving restocking programmes. The released numbers accounted for $<1\%$ of the total production of fingerlings because almost all fingerlings had to be sold on the market. A stocking ceremony took place in Heilongjiang in 2001, sponsored by the Heilongjiang Government, the Heilongjiang Fisheries Bureau and the Fisheries Bureau of Fuyuan County whereby 20 000 Kaluga and 130 000 Amur sturgeon fingerlings (5–10 cm) and 3000 Amur sturgeon juveniles (1.5 kg) were released in the Amur River. It was the first time that Kaluga, a critically endangered species, was released into the Amur River. Also 50 000 Amur sturgeon juveniles (5 cm) were released in the Amur River in 2002. These fish were provided by the Fuyuan Sturgeon Propagation Station (Hatchery), Heilongjiang Provincial Endemic Fish Institute at Jiamusi, Heilongjiang.

Table 13
Sturgeon hatcheries granted licences by the Heilongjiang Fisheries Bureau up to the end of 2002

Name	Location
Fuyuan Sturgeon Propagation Station	Fuyuan County
Qingdeli Sturgeon Propagation Station	Qingdeli Farm
Heilongjiang Provincial Endemic Fish Institute	Jiamusi City
Heilongjiang Global Fisheries Inc.	Harbin City
Jixi Fisheries Research Institute	Jixi City
Tongjiang Bacha Sturgeon Base	Bacha Town, Tongjiang City
Tongjiang Yinchuan Sturgeon Base	Tongjiang City

Restocking capability. Unfortunately, a scientific stock assessment for the Amur sturgeon or the Kaluga in the Amur River is lacking. Therefore, the effect of any rehabitation programme is difficult to assess. Nevertheless, harvest records documented by the Heilongjiang Fisheries Bureau show that the populations of both species have declined and that the Kaluga may be near extinction. At the present time, it is difficult to predict how many fish could be caught without harming wild populations.

Currently the rearing facilities in Heilongjiang are sufficient to produce sturgeon for stocking. However, the rearing tanks and related facilities need to be improved and expanded. Fingerlings could also be raised in the southern regions and transported back to the Amur River for release. Using various propagation strategies, it will certainly be possible to release millions of fingerlings.

Discussion and conclusions

There are eight indigenous species of Acipenseriformes in China, all of which are endangered because of various human activities. Commercial farming of sturgeons has become popular since 1998. There are 11 species and hybrids presently cultured, including imported species and hybrids from Russia, France and Hungary. *Acipenser schrenckii* and an Amur hybrid (*A. schrenckii* × *H. dauricus*) that are the major objects of commercial culture. Sturgeon aquaculture occurs in about 20 provinces, with major centres in the Pearl River delta, the Yangtze delta, Fujian and Hubei provinces. However, the two deltas may not actually be the best areas of China for sturgeon aquaculture as a result of the water quality and temperature.

According to existing laws and regulations related to wildlife, all sturgeon and paddlefish species are protected as Class 1 or Class II animals. Commercial utilization requires special licenses, as described in relevant regulations such as the 'Regulation on special license of aquatic wildlife utilization of the PRC'. The authors believe that the existing Chinese laws and regulations do not accommodate sturgeon farming, which has become a routine part of aquaculture in the country.

The quantity of sturgeon produced by aquaculture in China appears to be the largest in the world as of 2000. Based on the two surveys, we estimate that the total capacity of production of 0.75 kg fish from all aquaculture facilities combined is about 15 700 tonnes. The current number of fingerlings of all sturgeon species and hybrids is about 17.86 million, and the

standing biomass of the grown-out fish above 1 year of age is about 1500 tonnes. We predict that production of 0.75 kg size fish will exceed 6000 tonnes by May 2003, assuming a 50% survival ratio of these fingerlings in farming.

Because the current market in China only accepts about 0.75 kg size live sturgeon and whereas sturgeon farming has greatly increased, sturgeon prices have sharply dropped in the last 5 years (Wei, 2002). Sturgeon weighing 0.75 kg are juveniles; the sale of this size of fish brings sturgeon culturists very low or negative profits and is a waste of sturgeon resources. The recent discovery of international or domestic markets that accept processed production of reared sturgeon is beneficial for the development of both sustainable sturgeon culture and wild population conservation. Finally, a sustainable sturgeon industry in China should produce as many products as possible (meat, caviar, medicine and leather) from farmed sturgeon.

The introduction of millions of fry of exotic sturgeon species and their hybrids to China will negatively impact native sturgeon species, sturgeon biodiversity and sturgeon ecosystems (A. Wakeford, 2001; Shortnose Sturgeon Recovery Team, 1998). We believe that it is unnecessary to import non-native sturgeons; it is possible to provide enough fry for aquaculture through captive breeding of native species such as *A. schrenckii, A. sinensis* and *H. dauricus*. Hatcheries should also be very cautious with open-water rearing of sturgeons in net cages, even if this culture mode greatly reduces rearing costs.

The Chinese government should enforce the CITES convention on the control of caviar export quotas. However, the harvest of *A. schrenckii* and *H. dauricus* might exceed the relevant catch quotas granted by CITES, since artificial breeding for commercial aquaculture filled their quotas in 1998–2002. Uncontrolled development of sturgeon farming will threaten the wild sturgeon populations in the Amur River where they are already endangered.

Development of sustainable sturgeon aquaculture for both commercial and conservation purposes is hindered by a shortage of higher-age stock or pre-broodfish in captivity. Preserving sufficient higher-age fish annually and development of captive breeding populations of *A. sinensis, A. schrenckii* and *H. dauricus* should be national priorities in fisheries science and management.

Recommendations for future research and conservation programmes

A national action plan should be promptly worked out for the conservation of Chinese sturgeons and paddlefish to provide a firm guideline on conservation strategies and aquaculture development.

To prevent extinction of the three species (*A. sinensis*, *A. dabryanus* and *P. gladius*) in the Yangtze River, a specific foundation should be set up by the Chinese government to guarantee continued and long-term support for the establishment of captive 'backup populations' (captivity) of the three species and for their habitat protection and/or restoration, as well as a restocking programme and the commencement of relevant accompanying scientific studies. According to the relatively stable status of wild populations of *A. sinensis* in some areas and the huge costs in setting up the necessary 'backup population' large enough for such big fish, limited commercial farming of the species should be permitted with the goal to raise the necessary financial resources for a solid rehabitation programme, rather than a haphazard approach that would negatively impact their natural populations (gene pool).

Stock assessment of *A. schrenckii* and *H. dauricus* has to be immediately removed from routine management and should be done by scientists because of the many open questions as to the required methodology. Catch quotas should be based on the results of scientific investigations rather than on official statistics of harvest records. We suggest that a cooperative research team for the Amur sturgeons should be organized, taking responsibility for appropriate stock assessment procedures and to also evaluate the effectiveness of restocking. Harvest quotas must include due consideration of both catches for caviar and necessary breeding programmes in aquaculture.

Governments of the state and the provinces should encourage and lead culturists as well as monitor markets so that only larger-size farmed sturgeons are sold in order to save sturgeon stocks while also reducing rearing costs.

Sturgeon restocking programmes in the Amur River have to be developed jointly by both China and Russia using a common strategy. The two countries should enhance their cooperation to co-investigate and co-manage their sturgeon stocks to gain the best efficiency on each side.

Legislation related to aquatic wildlife including sturgeons has to be expedited; especially relevant regulations have to be amended to encompass fully the new situation faced by both wildlife conservation and economic development. In the very near future, regulations or policies related to sturgeon aquaculture management should be formulated and strictly enforced, such as the location of farms as well as measures to prevent cultured sturgeons from escaping to sturgeon rivers where they may negatively influence wild stocks. Especially hybridization of escaped cultured specimens with endangered wild sturgeons must be prevented to preserve their gene pool.

An association of sturgeon conservation and management should be set up to control sturgeon aquaculture, to raise money from sturgeon users to feed back to sturgeon conservation.

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References

Anonymous, 1988: The biology of the sturgeon in Yangtze and their artificial propagation. The Yangtze Aquatic Resources Survey Group. Sichuan Scientific and Technical Publishing House, 284 pp (in Chinese).

Bronzi, P.; Rosenthal, H.; Arlati, G.; Williot, P., 1999: A brief overview on the status and prospects of sturgeon farming in Western and Central Europe. J. Appl. Ichthyol. **15,** 224–227.

Burtsev, I. A.; Nikolaev, A. I.; Maltsev, S. A.; Igumnova, L. V., 2002: Formation of domesticated broodstocks as a guarantee of sustainable hatchery reproduction of sturgeon for sea ranching. J. Appl. Ichthyol. **18,** 655–658.

Chang, J., 1999: Structure and dynamics of the spawning stock of Chinese sturgeon, *Acipenser sinensis*, in the Yangtze River.

Doctoral dissertation, Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan, China, pp. 3–136.

Chang, J.; Cao, D., 1999: History and prospect of conservation on Chinese in the Yangtze River. Acta Biol. Sinica **239,** 712–720 (in Chinese).

Chebanov, M. S.; Karnaukhov, G. I.; Galich, E. V.; Chmir, Yu. N., 2002: Hatchery stock enhancement and conservation of sturgeon, with an emphasis on the Azov Sea populations. J. Appl. Ichthyol. **18,** 463–469.

Chen, S.; Zhou, X., 1992: studies on the artificial spawning of *Acipenser schrenckii*. Heilongjiang Fisheries **4,** 8–12 (in Chinese).

Chinese Academy of Science, Yangtze River Water Resources Protection Institute, 1996: Transaction of the impacts of three gorges hydroelectric project on environments (Summary). Chinese Sci. Press, Beijing, 64 pp (in Chinese).

Leng, X.; Cao, D., 1999: Trials of grow-out sturgeon raising in net cages. Freshw. Fish **4,** 44–45 (in Chinese).

Office of Aquatic Wildlife Conservation of MoA, 2002: Collections of Laws and regulations involved in aquatic wildlife of China. China Legal Publishing house, Beijing, pp. 63–169 (in Chinese).

Qu, Q.; Sun, D.; Ma, W., 2002: A note report on artificial reproduction of Amur sturgeon, *Acipenser schrenckii*. J. Fish. Sci. China **9,** 275–279 (in Chinese).

Raymakers, C.; Hoover, C., 2002: Acipenseriformes: CITES implementation from Range States to consumer countries. J. Appl. Ichthyol. **18,** 629–638.

Ri, D., 1997: The largest sturgeon farm in Asia being setting up in Liaoning, China. Chin. Fish **7** (in Chinese).

Shortnose Sturgeon Recovery Team, 1998: Final recovery plan for the shortnose sturgeon (*Acipenser brevirostrum*). US Dept. Commerce and Nat. Mar. Fish. Serv., NOAA, 104 pp.

Sun, D.; Qu, Q.; Ma, G., 2003: The status of sturgeon culture in China. J. Dalian Fish. Univ. **18,** 216–221 (in Chinese).

Wei, Q., 2002: On the direction of sturgeon industry of China. Sci. Fish Farm. **151,** 3–4 (in Chinese).

Wei, Q., 2003: Reproductive behavioral ecology of Chinese sturgeon (*Acipenser sinensis*) with its stock assessment. Doctoral dissertation, Graduate School of Chinese Academy of Science, Beijing, China, 122 pp (in Chinese).

Wei, Q.; Yang, D., 1998: Strategy of conservation of sturgeons and paddlefish in the Yangtze River, the 21 Century's Ecological Environment and Conservation in Large Hydroelectric Projects on the Yangtze River. The Chinese Environment Press, Beijing, pp. 208–216 (in Chinese).

Wei, Q.; Yang, D., 2003: Conservation and management of sturgeons and paddlefishes in China and their industrialization. Freshw. Fish **33,** 3–7 (in Chinese).

Wei, Q.; Ke, F.; Zhang, J., 1997: Biology, fisheries and conservation of sturgeons and paddlefish in China. Environ. Biol. Fish. **48,** 241–255.

Wu, Y.; Lin, J., 1999: American paddlefish and its aquaculture. Freshw. Fish **1,** 38–39 (in Chinese).

Yang, F., 1997: The sturgeon stock resources and the ways of its protection and development in China. Resources Development and Markets. **13,** 195–199 (in Chinese).

Yang, D.; Wei, Q.; Wang, K., 2004: The restocking of yearling Chinese sturgeon (*Acipenser sinensis*) in the Yangtze River and their migration and distribution. Acta Hydrobiol. Sinica (in press, in Chinese).

Zhang, J., 1985: Fishery resources of Heilongjiang Province. The Chaoxian Nationality Publishing House of Heilongjiang, Mudanjiang, China, pp. 352–389 (in Chinese).

Zhuang, P.; Kynard, B.; Zhang, L.; Zhang, T.; Zhang, Z.; Li, D., 2002: Overview of biology and aquaculture of Amur sturgeon (*Acipenser schrenckii*) in China. J. Appl. Ichthyol. **18,** 659–664.

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